A Time Series model for the effect of diesel prices on Food and non-Alcoholic Beverage CPI prices in Namibia 2017-2021

by

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Abstract

Fuel is an energy source that plays an important role in the economy of most countries and its fluctuating prices affect most sectors in the economy. This study investigated the effect of diesel prices on food and non-alcoholic beverages CPI in Namibia. Descriptive statistics were computed, time and scatterplots; ACFs and a time series regression model was explored to investigate the relationship between food and non-alcoholic beverages CPI and average diesel prices and an Auto Regressive Integrated Moving Average (ARIMA) model was used to forecast future values upon monthly time series data for 2022. There was an upward trend in both diesel prices and food and non-alcoholic beverages CPI over the period. There was a weak positive association between average diesel prices and food and non-alcoholic beverages CPI. The effect of average diesel prices (t=0.7582, p=0.4515) in the time series regression equation $y_t = -1.6330 + 0.0773x_t + 1.0076y_{t-1} + \varepsilon_t$ was not statistically significant. The ARIMA (0,2,1) model for food and non-alcoholic beverages CPI was significant (p<0.001) and was deployed for forecasting.

Keywords: diesel prices, CPI, Namibia, time series forecasting, ARIMA

1. Introduction

Diesel Fuel is an energy source that plays an important role in the economy of most countries and its fluctuating prices affect most sectors of the economy (Katircioglu et al., 2015; Habanabakize & Dickason-Koekemoer, 2021). Brent crude oil was $57.10 per barrel in January 2017, but plummeted to $13.77 per barrel in April 2020 and has risen steadily ever since (Macrotrends, 2022). According to a report by Bank of Namibia (BoN) (2020), domestic inflation has fallen to a historical low, and overall inflation declined to 2.2% in 2020, which is a 1.5% point fall from 2019 with deflationary pressure from excess supply in the rental market and low international oil prices.

Consumer Price Index (CPI) is a measure that examines the weighted average of prices of a basket of consumer goods and services (Fernando, 2022). In Namibia, the CPI also referred to as Namibia Consumer Price Index (NCPI), is used as the basis to calculate the rate of inflation as experienced by consumers (Namibia Statistics Agency, 2021, p.3). Namibia Statistics Agency (NSA) explained in their report that the inflation rate measures the change in CPI for the month under consideration from the previous month (month-to-month change) as well as with the corresponding month of the previous year (year-to-year changes). The report further stated that the inflation rate is very important for economic policy-making, in particular for the implementation of monetary policy and for consumers in general. In October 2021, the annual rate of inflation increased by 3.6% compared to 2.3% recorded in October 2020. Monthly, the rate slowed to 0.2% from 0.3% recorded a month earlier. The main factors contributing to the annual rate of inflation were transport (1.5% points), food and non-alcoholic beverages (1.0% points) (Namibia Statistics Agency, 2021, p.3).

High inflation increases the producer's cost of production and leads to a decrease in the purchasing power of consumers (Fedderke & Liu, 2018). By affecting energy-intensive inputs, which directly affect transportation costs, changes in oil prices directly affect the cost of food production, and therefore food prices (Baumeister & Kilian, 2014). Fluctuations in food prices can be a problem for a growing economy like Namibia's. An increase in the economy's overall price level over a period of time can have serious consequences (Shilongo, 2019). Namibia mostly depends on South Africa for imports which imply that an increase in the price levels in South Africa will be passed on to Namibia, resulting in inflationary pressure to Namibia. If Namibia has higher inflation rates than its trading partners, it would cause Namibia to buy more of the imported goods as local goods and services would become costlier in comparison to those of the trading partners, which consequently might lower economic growth (Munepapa & Sheefani, 2017).

The relationship between the price of oil and food prices has attracted much attention in the public debate (Meyer et al., 2018). There have been a few studies done on the relationship of fuel prices and food prices, with each study having their own focus point (Ngare & Derek, 2019; Zmami & Ben-Salha, 2019; Habanabakize & Dickason-Koekemoer, 2021; Kpodar & Liu, 2022). However, there are not many studies based on Namibia, most studies have been carried out in other countries in Africa and overseas.

Ngare and Derek (2019) evaluated the effect of fuel prices on food prices in Kenya by testing for Granger causality and cointegration applied to diesel, maize, beans, cabbage and potato price data for the period 2010-2018. The study found that diesel prices affect cabbage and potato price but did not affect maize and bean prices and also suggested that there is a long run price relationship between perishable foods and fuel prices with an increase in the price of diesel resulting in a significant increase in the price of cabbages and potatoes.

Kpodar and Liu (2022) investigated the response of consumer price inflation to changes in domestic fuel prices, looking at the different categories of the overall CPI by using the local projections method which generates multi-step predictions using direct forecasting models that are re-estimated for each forecast horizon. The study concluded that the response of inflation to gasoline price shocks is smaller yet more persistent and broad-based in developing economies than advanced economies which ultimately leads to a higher consumer price level for the average developing economy.

Habanabakize and Dickason-Koekemoer (2021) assessed the effects of electricity supply, inflation and fuel prices on food and beverage production and sales in the manufacturing sector using different econometric approaches such as the Johansen test for cointegration, vector error correction model (VECM) and Granger causality test on monthly time series data from 2002 to 2019. The study found the existence of a joint long-run relationship between electricity distribution, inflation rate, fuel price, production and sales of both food and beverages within the manufacturing sector.

Zmami and Ben-Salha (2019) aimed to conduct aggregated and disaggregated analyses of the impact of oil prices on international food prices between January 1990 and October 2017. The empirical investigation was based on the estimation of linear and non-linear autoregressive distributed lag (ARDL) models. The study confirmed the presence of asymmetries since the overall food prices is only affected by positive shocks on oil price in the long-run.

Regression analysis is a statistical technique for modelling and investigating the relationships between an outcome variable and one or more predictor variables (Montgomery et al., 2015). The time series regression model for CPI is as follows:

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t, \quad \varepsilon_t = \phi\varepsilon_{t-1} + a_t$$

where y_t is food and non-alcoholic beverage prices CPI at time t, x_t is the average diesel prices at time t; and ε_t is the error term in the model at time period t, a_t is an NID (0, σ_a^2) random variable, and ϕ is a parameter that defines the relationship between successive values of the model errors ε_t and ε_{t-1}. The regression model assumptions are that: there exists a linear relationship between the independent variable and the dependent variable; the error term is normally distributed, variance is constant (no heteroscedasticity), and there is independence of the observations.

The Durbin-Watson test is a statistical test for the presence of positive autocorrelation in regression model errors. The hypotheses in the Durbin-Watson test are $H_0: \phi = 0$ and $H_1: \phi > 0$

The Durbin-Watson test statistic is given by

$$d = \frac{\sum_{t=2}^{T}(e_t - e_{t-1})^2}{\sum_{t=2}^{T} e_t{}^2} = \frac{\sum_{t=2}^{T} e_t{}^2 + \sum_{t=2}^{T} e_{t-1}{}^2 - 2\sum_{t=2}^{T} e_t e_{t-1}}{\sum_{t=2}^{T} e_t{}^2} \approx 2(1 - r_1),$$

where the e_t, $t = 1,2, \ldots, T$ are the residuals from an ordinary least square (OLS) regression of y_t on x_t. r_1 is the lag one autocorrelation between the residuals. The decision procedure is as follows: if $d < d_L$ reject $H_0: \phi = 0$; if $d > d_U$ do not reject $H_0: \phi = 0$; and if $d_L \leq d \leq d_U$ the test is inconclusive, where d_L is lower bound and d_U is upper bound (Montgomery et al., 2015). The Autocorrelation Function (ACF) is a set of serial correlation coefficients i.e. the correlation coefficients of pairs of successive values of the time series variable. The lag k autocorrelation function is defined as

$$r_k = \frac{\sum_{i=1}^{N-k}(Y_i - \bar{Y})(Y_{i+k} - \bar{Y})}{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}$$

The assumption is that the observations are equally spaced over time.

The Auto Regressive Integrated Moving Average (ARIMA) model is a class of models that explains a given time series based on its own lags and lagged forecasts, to forecast future values. ARIMA is characterized by 3 terms, namely: (p, d, q) with p being the AR term, d being the number of differencing required to make the time series stationary, and q is the order of MA term. The general formula for ARIMA model is:

$$Y_t = \alpha + \beta_1 Y_{t-1} + \ldots + \beta_p Y_{t-p} + \varepsilon_t + \phi_1 \varepsilon_{t-1} + \ldots + \phi_q \varepsilon_{t-q}$$

where, α is a constant, $\beta_1 Y_{t-1} + \ldots + \beta_p Y_{t-p} \varepsilon_t$ is the linear combination of lags of Y up to p lags and $\phi_1 \varepsilon_{t-1} + \ldots + \phi_q \varepsilon_{t-q}$ is the linear combination of lagged forecast errors up to q lags (Prabhakaran, 2021).

Most of the relevant studies have been conducted in other countries and there is limited evidence based on Namibia. This paper examined the trends that occur monthly and relate food prices using CPI to diesel prices in Namibia.

2. Methods

This study adopted a quantitative based on secondary monthly time series data for the period 2017 to 2021. The study variables included average diesel prices measured in terms of Namibian dollars (N$) per litre, the independent variable and food and non-alcoholic beverage price as the dependent variable CPI measured in points which was the dependent variable. The data for diesel fuel prices was received from Ministry of Mines & Energy, and the data for food and non-alcoholic beverage prices CPI was sourced from the data portal of Namibia Statistical Agency (NSA). Statistical descriptive summaries in form of measures of centrality and dispersion were computed. The time series regression model was used to investigate the relationship between the dependent and independent variables. Time series plots establish the components were constructed and time series regression models were explored. The Durban-Watson test was used to test for autocorrelation of errors. The autocorrelation function was used to detect stationary or non-stationary. The Auto Regressive Integrated Moving Average (ARIMA) Model was used to forecast prediction values. The statistical software used were RStudio version 1.41103.

3. Results

Over the study period 2017 to 2021, the average diesel price ranges from N$10.80 to N$15.40 with a mean of N$12.96 and standard deviation of 1.27 (95% CI 12.63-13.28). The food prices CPI ranges from 136.3 points to 167.6 points with a mean of 149.60 points and standard deviation of 9.97 (95%CI 147.04-152.09). Figure 1 shows the time series plots of the average diesel prices and food and non-alcoholic beverage CPI. There was an upward linear trend on food and beverage CPI points, the lowest point being between 2017 and 2018, with the highest point between 2021 and 2022. Diesel prices also exhibited an overall upward trend with some cycle. Figure 2 shows that the ACFs of the average diesel prices and the average Food and non-alcoholic beverage CPIs were both not stationary.

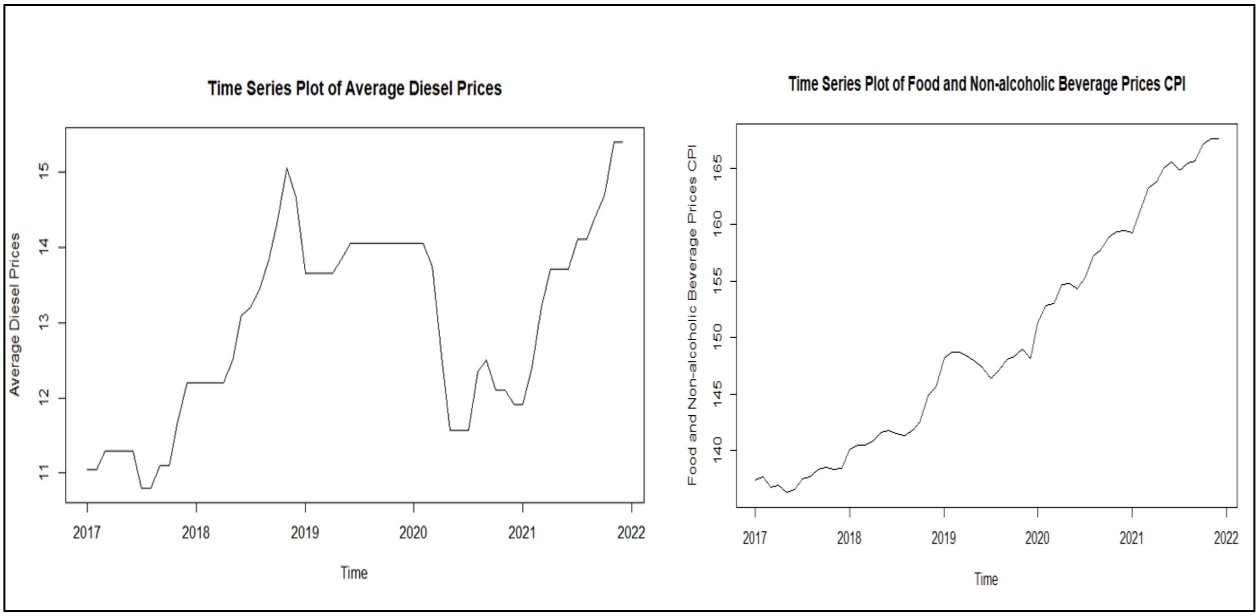

Figure 1: Time series Plots of Average Diesel prices and Food and non-Alcoholic beverage Prices CPI

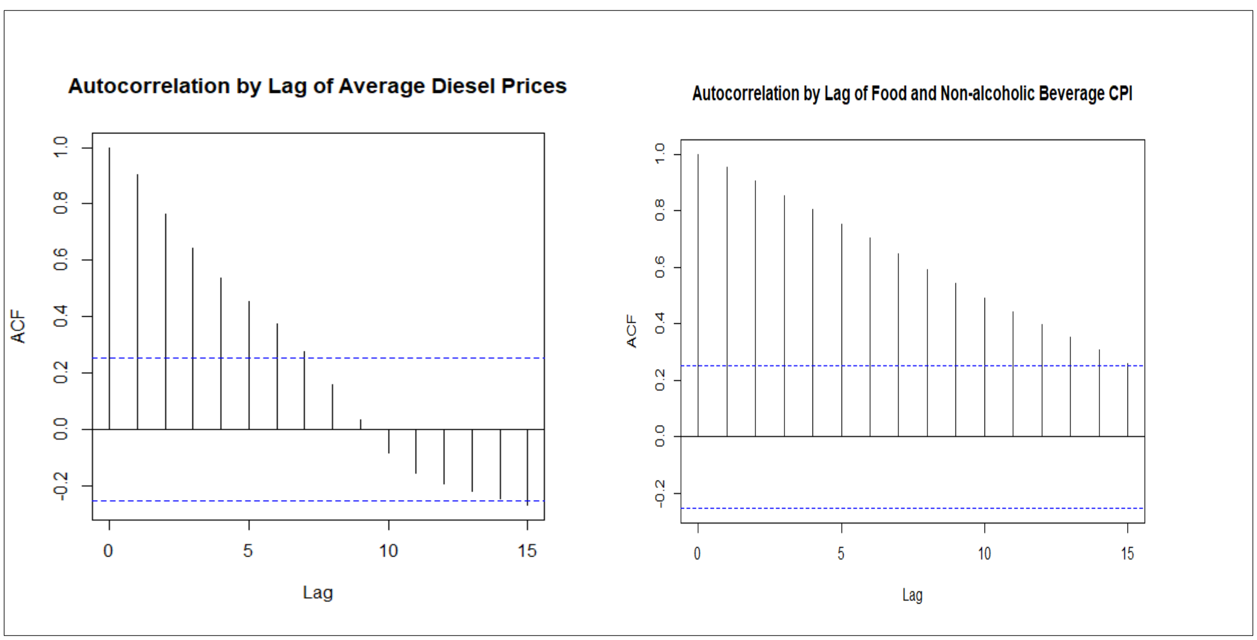

Figure 2 ACF of Average Diesel Prices and Food and non- alcoholic beverage CPI

There was a significant moderate positive relationship between the average diesel prices and the food and non-alcoholic beverage prices CPI (r=0.54, p=<0.001. An increase in the value of average diesel prices was associated with an increase in food and non-alcoholic beverage prices CPI. Kolmogorov-Smirnov test showed that both average diesel prices (p=0.0535 and Food and non-alcoholic beverage CPI (p=0.2308) data were normally distributed.

The regression equation $y_t = 99.6830 + \ 3.849x_t$ showed that each additional one dollar increase in Average Diesel Prices (x_t) was associated with an average increase of $3.85 in Food & Non-alcoholic Beverage Price CPI (y_t). The F-statistic = 18.49 with p-value =<0.001, showed that the regression model was statistically significant. The coefficient of determination (22.87%) showed that the variability observed in Food & Non-alcoholic beverages was poorly explained by the regression model. See Table 1.

Table 1. Summary of initial regression model Results

Variable	**Estimate**	**Std. Error**	**t-value**	**Pr (>|t|)**
Intercept	99.6830	11.6557	8.552	7.32e-12
Average Diesel Prices	3.8495	0.8952	4.300	6.62e-05

Multiple R-squared: 0.2418, Adjusted R-squared: 0.2287, F-statistic: 18.49, p-value: 6.618e-05

The Durbin-Watson statistic d= 0.0410, which was below the lower bound of 1.55, suggesting that autocorrelation was present in the residuals. To fix the problem of autocorrelation present, the 1 period lag of the dependent variable was added as an independent variable, $y_t = \beta_0 + \ \beta_1 x_t + \beta_2 y_{t-1} + \ \varepsilon_t$, which gave the following output in Table 2.

Table 2. Revised regression model after 1 period lag added as independent variable

Variable	Estimate	Std. Error	t-value	Prob.
Intercept	-1.6330	1.7821	-0.9163	0.3634
Average Diesel Prices	0.0773	0.1020	0.7582	0.4515
1Lag Food & Non-alcoholic Beverage CPI	1.0076	0.0131	76.6682	0.0000

Durbin-Watson statistic: 1.7644, Adjusted R-squared: 0.9924, R-squared: 0.9927

From Table 2, the regression equation $y_t = -1.6330 + 0.0773x_t + 1.0076y_{t-1} + \varepsilon_t$ gave a Durbin-Watson statistic of 1.7644 which is above the upper bound of 1.62, therefore concluding that autocorrelation is no longer present. However, the Average diesel prices were no longer a significant predictor of food and beverage CPI (t=0.7582, p=0.4515), but only the 1 lag Food and non-alcoholic beverage CPI (t=76.668, p<0.001).

Since the Food & Non-alcoholic Beverage CPI time series was non-stationary, the series was differenced to transform them to stationarity. The Food & Non-alcoholic reached stationary after taking the second order differencing, setting d=2. The Partial Autocorrelation (PACF) was used to find the number of AR terms, all the lags had no significance, therefore we set p=0. The Autocorrelation (ACF) was used to find the number of MA terms, since none of the lags are above the significant limit, we set q=0. Since the series was slightly over-differenced, we added one MA term, therefore setting the new q=1. The ARIMA (0,2,1) model $Y_t = \alpha - 0.9495\varepsilon_{t-1}$ was highly significant (p<0.001). The Box-Ljung test with p-value = 0.4757 > 0.05, indicated that the residuals were independently distributed. Using ARIMA (0,2,1) forecasts were made for Food & Non-alcoholic Beverages CPI for 2022. See Figure 3 and Table 3. The ARIMA (0,2,1) forecast for Food & Non-alcoholic Beverages CPI in showed a prediction of gradual increase in the CPI points. The CPI point in December 2021 was 167.62 with a point forecast of 174.82 in December

2022 from Table 8, which has a difference of 7.2. This was not far off from the difference of 8.16 from December 2020 with 159.46 points to December 2021.

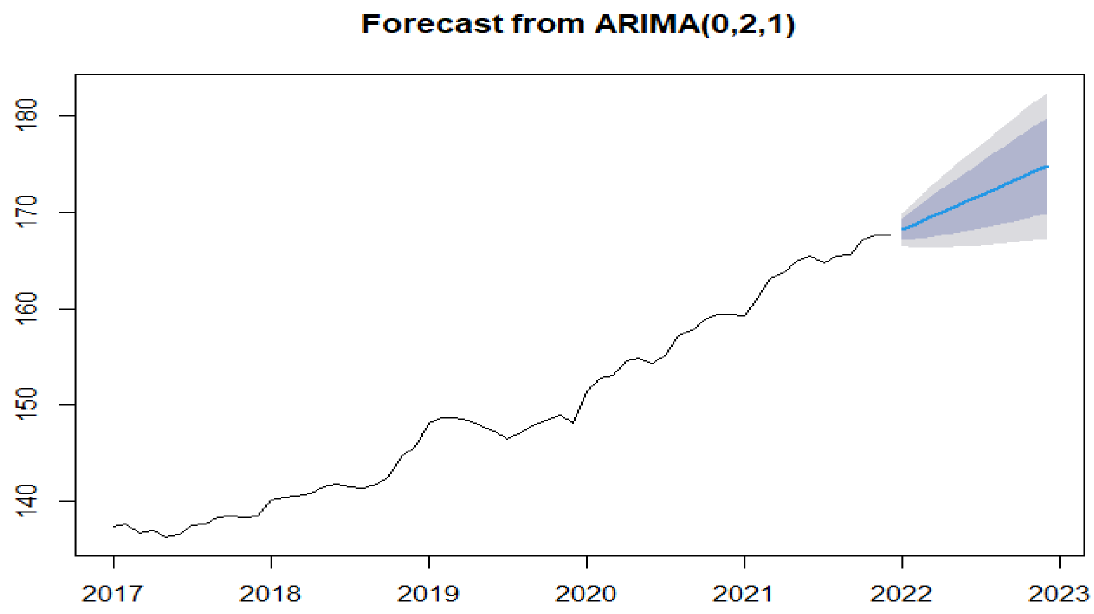

Figure 3. ARIMA (0,2,1) Forecast for Food & Non-alcoholic Beverages CPI

Table 3. ARIMA (0,2,1) Point Forecast of Food & Non-alcoholic Beverages CPI

	Point Forecast	**Lo 99.5**	**Hi 99.5**
Jan 2022	168.22	165.77	170.66
Feb 2022	168.82	165.27	172.37
Mar 2022	169.42	164.96	173.87
Apr 2022	170.02	164.75	175.29
May 2022	170.62	164.58	176.65
Jun 2022	171.22	164.45	177.99
Jul 2022	171.82	164.34	179.30
Aug 2022	172.42	164.23	180.60

Sep 2022	173.02	164.14	181.89
Oct 2022	173.62	164.06	183.18
Nov 2022	174.22	163.97	184.47
Dec 2022	174.82	163.89	185.75

4. Discussion

The study found that there was a weak positive relationship between the diesel prices and food and non-alcoholic beverage CPI, which is consistent with Kpodar and Liu (2022) that the response of inflation to gasoline price shocks is smaller yet more persistent and broad-based in developing economies. The data suggested that diesel prices affect food and non-alcoholic beverage CPI which is consistent with the study done by Habanabakize and Dickason-Koekemoer (2021) that there is a joint long-run relationship between electricity distribution, inflation rate, fuel price, production and sales of both food and beverages.

The study found that there was an upward trend in both diesel prices and food and non-alcoholic beverage CPI, with a repeating pattern in the seasonal component. According to the study a decrease in diesel prices did not necessarily cause a consequent decrease in food and non-alcoholic beverage CPI, which is consistent with the study done by Zmami and Ben-Salha (2019) that the overall food price is only affected by positive shocks on oil price in the long –run.

However, before the final increase price of diesel is finalized in Namibia, unit rate slate calculations are done that influences the final price. Such as the exchange rate (AVG. MNTH. N$ /USD), average world-scale freight rates, fuel tax, Walvis Bay landed cost, road user charge, industry margin, to name a few.

5. Conclusion

The study aimed to investigate the effect of diesel fuel prices on food and non-alcoholic beverages CPI in Namibia. The study concluded that diesel prices have positive but not significant effect on food and non-alcoholic beverage prices. The limitation of the study was that it focused only on diesel prices and food & non-alcoholic beverage CPI from 2017-2021, while there are many other factors that can contribute to changes in CPI. The uniqueness of this study is that there are not many studies previously conducted analysing the effect of diesel prices on food and non-alcoholic beverages CPI in Namibia.

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